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REVISITING ORGANIZATIONS AS INFORMATION PROCESSORS: ORGANIZATIONAL STRUCTURE AS A PREDICTOR OF NOISE FILTERING

by

Kevin L. Fournier

June 2008

Thesis Advisor:	Karl Pfeiffer
Second Reader:	Diana Petross

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By comparing the information processing behaviors of four groups of mid-level working professionals as each undertakes a series of four complex, interdependent, computer-mediated decision-making exercises, this thesis explores 1) how processing of information in effective [i.e., high-performing] groups differs from the processing of information in ineffective [i.e., low-performing] groups, and 2) the characteristics of adaptation, from an information processing perspective, within high performing groups. The results of the exploration, though mostly inconclusive, call into question both intuition and literature regarding organizational structure as well as literature in information and knowledge sharing. It is predicted that meaningless (noise) information will be shared less as time passes and individuals learn. It is also hypothesized that as less noise is shared the organizations' performance will increase.

As an explanation, this thesis proposes that the ability to filter noise not only increases over time, but is also dependent on the organizational structure further explaining why one structure consistently outperforms another organizational structure. Further experimentation is needed to test the validity of these conjectures and bring better understanding to Organizational Theory, Information Processing and Knowledge Sharing networks.

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REVISITING ORGANIZATIONS AS INFORMATION PROCESSORS: ORGANIZATIONAL STRUCTURE AS A PREDICTOR OF NOISE FILTERING

Kevin L. Fournier
Captain, United States Air Force
B.S. Computer Science, Hawaii Pacific University, 2002

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NAVAL POSTGRADUATE SCHOOL
June 2008

Author: Kevin L. Fournier

Approved by: Karl Pfeiffer
Thesis Advisor

Diana Petross
Second Reader

Professor Dan Boger
Chairman, Department of Information Sciences

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As an explanation, this thesis proposes that the ability to filter noise not only increases over time, but is also dependent on the organizational structure further explaining why one structure consistently outperforms another organizational structure. Further experimentation is needed to test the validity of these conjectures and bring better understanding to Organizational Theory, Information Processing and Knowledge Sharing networks.

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I. INTRODUCTION

There have been many studies conducted over the years to evaluate the performance of organizations; however none have focused on the specific characteristic of noise filtering as an explanation for increased organizational performance. The advances of computer mediated experimentation have given researchers increased control over the collection of data; increased volume of data collected; and more computational power. This in-turn gives researchers the power to make more confident assertions about organizational behaviors. This thesis uses these techniques to explore 1) how processing of information in effective [i.e., high-performing] groups differs from the processing of information in ineffective [i.e., low-performing] groups, and 2) the characteristics of adaptation, from an information processing perspective, within high performing groups.

A. PURPOSE AND MOTIVATION

Organizations have been the topic of research for many years now, specifically which organizational structures perform better and in what situations. As organizations transition from the Industrial Age into the Information Age and as task complexity increases it is becoming apparent that the many contemporary structures are often unsuited to perform well in their environments. Organizations from the Industrial Age typically exhibit "anti-sharing, and anti-collaborative" behaviors which are characteristic of hierarchies and bureaucracies which were normally used in that era and are counterproductive whether in industry, government or defense.[1] Given the present day's complexity; the focus of labor has shifted to one that requires more collaboration, better information processing and increased knowledge sharing. It has been argued that in order to maintain a strategic foothold and achieve tactical success, management must redefine their structure and take advantage of lateral and vertical agility and cross-communication

[1] David S. Alberts and Richard E. Hayes, *Power to the Edge* (Command and Control Research Project, 2003), 73.

between different levels of personnel within the organization.[2] Boyd (1987) said we must uncover those interactions that foster harmony and initiative while not disrupting or destroying variety and speed.[3]

B. METHOD

A series of experiments took place in the Information Sciences Department of the Naval Postgraduate School from 10 January until 15 February 2007. During these experiments, the performances of two distinct types of organizations (Hierarchy and Edge) were examined in multiple groups and multiple sessions. The experiment details are summarized in Leweling & Nissen (2007). Although the hypotheses tested in this thesis were developed after the design and execution of the experiments, the data collected were so rich as to allow for exploration into areas not considered under the original scope of the experiments.

C. ANALYSIS

For this thesis, the author coded data from the log files generated during the ELICIT experiments into time demarcated matrices which were then evaluated for amounts of noise shared with other individuals or posted to one of the common screens (who, what, where or when). Through the use of the software the data was converted into reliable measures. The independent variables of information processing structure are: organizational type (edge, hierarchy) and knowledge sharing: (supported, not supported). The dependent variables of this thesis are time and accuracy which ultimately measures performance. The final step in the analysis is to examine the correlations between the independent and dependent variables.

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[2] Simon R. Atkinson and James Moffat, *The Agile Organization* (Command and Control Research Project, 2005), 158-159.

[3] Michael McCaskey, *Framework for Analyzing Work Groups* (Harvard Business School Note. Boston: Harvard Business School Publishing, 1996).

D. ORGANIZATION OF THESIS

In Chapter II, I present a survey of relevant Organizational Theory by Mintzberg (1983) as well as literature on knowledge sharing and information processing beginning with Nissen and ending with Tushman & Nadler (1978). Also, I will draw lightly on theories of networks by Monge & Contractor (2003). Much of my research will be grounded in work Chapter II concludes with my statement of hypotheses. In Chapter III, I build directly on work accomplished by Leweling (2007). Chapter III begins with an introduction to the ELICIT experiment. This introduction will cover a brief description of the ELICIT environment, its purpose and how it is organized; specifically the attempt to operationalize and compare the two different organizational forms (Hierarchy and Edge). Chapter III will also include the definitions of the measures used; specifically high performance and noise filtering. This chapter will conclude with a brief statistical analysis of how the measures will be applied to the information processing environment. Chapter IV details the statistical results of the research with respect to the hypotheses being evaluated. Chapter V summarizes the results from the statistical analysis and offers potential real world applicability. Chapter V concludes my thesis with a brief summary and suggestions for future research opportunities.

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II. LITERATURE REVIEW

This chapter will briefly review organizational theory from the view of information processing as a framework for viewing organizations in an effort to ground the research and analysis of this thesis. The specific organizational structures, Edge and Hierarchy, will be defined to permit further disciplined exploration of these forms. This chapter will close with statements of hypothesis for the present research.

A. ORGANIZATIONAL THEORY

Organizational theory reviewed in this section will cover the Mintzberg (1983) Structure of Fives, touching lightly on the different structures, their coordinating mechanisms and the primary organizational elements. The chapter then moves to Tushman & Nadler (1978) who view organizations as information processing systems. The section closes with the views of various researchers (e.g., Bush 1991; Arquilla & Ronfeldt 1996; van Alstyne 1997; Leweling 2007) on network organizations.

1. Mintzberg's Structures in Fives

According to Mintzberg (1983), organizations follow one of five distinct typologies, composed of one of five organizational elements and achieve coordination by one of five modes. Mintzberg's five typologies are: Simple Structure, Machine Bureaucracy, Professional Bureaucracy, Divisional Form and Adhocracy. The five elements of organization are: operating core, strategic apex, middle line technostructure and support staff. Each organization has these basic parts; the difference is how the different parts are emphasized from one structure to another. Also, all organizations rely on all modes of coordination however one mode tends to be dominant within any one organization. Mintzberg describes five modes of coordination: mutual adjustment, direct supervision, standardization of work processes, standardization of outputs and standardization of skills.

The Simple Structure is, as the name suggests, the simplest of all the forms. This form typically has little specialization, little formalization and little training. This form is believed to have as few as 3-4 similar external factors that influence the organization and can be compared to a "mom and pop" shop. This structure typically emphasizes the strategic apex. The strategic apex is the head of the administrative component and its duties are to: provide direct supervision; manage relationships with the outside environment; and develop strategy.[4] The mode of coordination utilized by the Simple structure is direct supervision, which is exactly what it sounds like; one person is placed in charge of others and is responsible for providing direction and monitoring subordinates' actions. The Simple structure tends to be quick and responsive, however it is considered to have little technostructure. This form, although very simple, is also very dynamic.[5]

The Machine Bureaucracy is characterized as very specialized, very formalized and stable. The Machine Bureaucracy relies on the standardization of work processes for coordination; the organization provides its laborers with a clear set of instructions to follow for specific tasks. In this structure the focus is on the technostructure element which becomes a key factor to the successful operation of the organization.[6] Technostructure is composed of analysts who are removed from the work flow, but still apply analytic techniques to the design or maintenance of the structure then train others. Although this form tends to be efficient and reliable it also tends to be impersonal and have an inflexible obsession with control. During the Industrial Era, this organizational form emerged as the best suited for its environment and repeatedly proved itself in mass producing goods, running governments and fighting wars.[7] This form is considered to be a hierarchical form which makes it one of the primary focus areas for this thesis.

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[4] Henry Mintzberg, *Structures in Fives: Designing Effective Organizations* (Upper Saddle River, New Jersey: Prentice Hall, 1983), 13.

[5] Mintzberg, *Structures in Fives*, 157-158.

[6] Mintzberg, *Structures in Fives*, 164-165.

[7] Alberts and Hayes, *Power to the Edge*, 37-49.

The third structure in Mintzberg's topology of five is the Professional Bureaucracy. This form, while sharing traits with the Machine Bureaucracy, is highly decentralized. The main element for this structure is the operating core, which is when the workers directly support their product or service. The Professional Bureaucracy is very specialized, has much training and is focused on standardization of skills to achieve coordination. This form works best in professional institutions and craft operations where counterparts learn what to expect from each other (i.e., doctors, teachers, accountants, etc).[8]

The next structure is the Divisional (diversified) form. This form has some specialization, some training and much formalization. It achieves coordination by using standardization of outputs which is a standard performance measure or specification concerning the outputs of work. This form is considered to be the middle line of structures which puts the emphasis on middle management or the people that sit between the strategic apex and the operating core. The Divisional form has self-contained unit groupings coordinated by a higher unit. The divisions may take any form or configuration mentioned.

The last typology addressed by Mintzberg (1983) is the Adhocracy. This form is similar to the Simple form in that it is highly organic with little formalization. The Adhocracy form achieves coordination through mutual adjustment. Mutual adjustment is the informal communication of individuals about their own work. The element focused on in this structure is the support staff. The support staff is all groups that provide indirect support to the rest of the organization (i.e., legal, public affairs, payroll, etc). It is very specialized, has much training and is complex and dynamic. This form tends to be innovative and flexible but ambiguous.[9]

Mintzberg also discusses his eight design parameters for organizations which are: job specialization, behavioral formalization, training and indoctrination, unit grouping, unit size, planning and control systems, liaison services and decentralization.

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[8] Mintzberg, *Structures in Fives*, 190.

[9] Mintzberg, *Structures in Fives*, 253-254.

Job specialization looks at a given job and how many tasks are associated with it in order to give control of the task to the workers. A job can be horizontally specialized or vertically specialized. Horizontally specialized jobs consist of a few narrowly defined tasks and are defined by how many types of tasks a worker accomplishes. Vertically specialized jobs give the worker little control over the tasks performed.

Behavioral formalization is simply the standardization of work process by using operating instructions, position, work flow, job descriptions and by rules. Training and indoctrination establishes and standardizes the required skills, knowledge and norms for a particular job by means of formal instructional programs. Unit grouping provides a fundamental means to coordinate work in the organization. It is responsible for four main effects on organizations: 1) it establishes a system of common supervision among positions and units; 2) requires positions and units to share common resources; 3) creates common measures of performance and 4) encourages mutual adjustment. Unit size refers to the number of positions a unit has and this directly affects the coordination mechanism.

Planning and control systems refer to the standardization of outputs which is divided into two categories: action planning system and performance control system. Liaison services is the whole set of mechanisms used to encourage mutual adjustment amongst the different units. The last parameter discussed is decentralization. Decentralization can be vertical or horizontal; vertical is when the decision making is delegated to the middle line managers or mid-management while the horizontal decentralization describes the process by which non-managers control the decision processes.[10]

2. Information Processing Systems

Another school of thought views organizations as information processing systems. Tushman & Nadler (1978) advocate viewing organizations in this manner. Information processing is the combination of gathering, interpreting and synthesizing of information

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[10] Henry Mintzberg, *Organization Design: Fashion or Fit?* (Harvard Business Review, January-February, 1981), 15.

for organizations to make decisions.[11] Tushman & Nadler (1978) define information as data which is accurate, concise, relevant and timely, which can then be used to effect a change in knowledge. Tushman & Nadler assert that organizations are open social systems which must deal with work-related uncertainty. Organizations are dependent on inputs from the environment and must be able to process uncertainties that are presented from sources beyond their control. Uncertainties can come from external and internal factors and as such the organization must develop mechanism to facilitate information processing.

Another assumption made by Tushman & Nadler (1978) is that given the myriad sources of uncertainty, the organization's structure should create the best configuration of work units to facilitate collecting, processing and distribution of information. Tushman & Nadler (1978) also assume that organizations can be viewed as being composed of subunits, each having to deal with a varying degree of uncertainty. These subunits share resources according to their position within the organization's structure and external environment.[12] Given the previous set of assumptions, Tushman & Nadler (1978) derive a series of five propositions:

Proposition 1: *The tasks of organizational subunits vary in their degree of uncertainty.*

The degree of uncertainty for an organizational subunit is a combination of three factors: subunit task characteristics (complexity and interdependence), stability of task environment and inter-unit task interdependence.[13]

Proposition 2: *As work related uncertainty increase, so does the need for increased amounts of information, and thus the need for information processing capacity.*

As uncertainty increases in a subunit so must the information processing capacity increase. Simply put, information processing requirements increase as the subunit faces a

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[11] Tushman and Nadler, "Information Processing as an Integrating Concept in Organizational.*" The Academy of Management Review* 3(3) (July 1978): 613-624.

[12] Tushman and Nadler, *The Academy of Management Review*, 614-615.

[13] Tushman and Nadler, *The Academy of Management Review*, 615-616.

greater amount of uncertainty. Likewise, if a subunit faces little uncertainty then there is a smaller requirement to process information.[14]

Proposition 3: *Different organizational structures have different capacities for effective information processing.*

Mechanistic structures typically do not have a high capacity for information processing and as such tend to operate best in stable environments that have less uncertainty. Organic structures, on the other hand, have an increased information processing capacity allowing them to more effectively deal with greater amounts of uncertainty, however, the greater capacity comes at a cost in time, effort, energy and managerial control. When considering increased information processing capacity one must weigh the benefits to the costs and potential increased response time.[15]

Proposition 4: *Organizations will be more effective when there is a match between information processing requirements facing the organization and information processing capacity of the organization.*

When an organization has extensive information processing requirements their performance is optimal when the organization's information processing capacity is high and likewise if the organization has minimal information processing requirements optimal performance comes when the information processing capacity if low. These would be considered a match between information processing requirements and information processing capacity. A mismatch occurs when the organization has extensive requirements and low capacity or minimal requirements and high capacity. Both efficient and optimal performance can be achieved only when there is a match.[16]

Proposition 5: *If organizations face different conditions over time, more effective units will adapt their structures to meet the changed information processing requirements.*

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[14] Tushman and Nadler, *The Academy of Management Review*, 616-617.

[15] Tushman and Nadler, *The Academy of Management Review*, 617-618.

[16] Tushman and Nadler, *The Academy of Management Review*, 619-620.

Work demands change constantly as time progresses, whether it is due to environmental conditions, program phase, technological changes or market conditions. In order for organizations to be fruitful they must structure towards a more dynamic approach and be flexible and adapt with the changes. As changes occur so does the information processing capacity of the organizations and to stay competitive, organizations must adapt their information processing structure.[17]

3. Network Organizations

Monge & Contractor (2003) argue that formal organizational structures have been researched so much that the utility of further research is questionable. They also go on to say it is preferable to study emergent structures.[18] There are many emerging organizational forms: strategic alliances, networked firms, Edge organizations (Leweling & Nissen 2007b) and bazaar-type organizations (Ishida 2002).

The advancements in technology, as well as technologies merging (communications and computers), have generated "virtual organizations" in which people are able accomplish work as if they were in the same space at the same time. "Virtual organizations" is a term that is interchanged freely with "network organizations" by Black & Edwards (2000).[19] Some scholars such as Tushman & Nadler (1978), Fombrun & Tichy (1979) and Krackhardt & Carley (1992) view these types of networks as something that lies between organizations. Other scholars, such as Podolny & Page (1991) view these types of networks as "any collection of actors ($N \geq 2$) that pursue repeated, enduring exchange relations with one another and, at the same time, lack a legitimate organizational authority to arbitrate and resolve disputes that may arise during the exchange." (p. 59)[20]

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17 Tushman and Nadler, *The Academy of Management Review*, 621-622.

18 Monge and Contractor, Theories of Communication Networks, 5.

19 Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 209.

20 Joel M. Podolny and Karen Page, "Network Forms of Organization," Annual Review of Sociology (1998), 59.

Van Alstyne (2002) describes network organizations as consisting of multiple disciplines such as: computer science, economics and sociology. Other researchers are not content to just describe network organizations by their disciplines but rather their centrality. Some researchers (Blau et al. 1976; Fry & Slocum 1984) argue technology is the central variable for network organizations.[21] However, Balkundi & Harrison (2006) postulate that organizations perform better when the leader is central to the team and the team is central to the network. John Boyd's thought was the more we know the more we connect: to the environment, the past, the future, to people, ideas and to things.[22] Similarly Atkinson & Moffat (2005) argue that network organizations are not about math, science or technology but rather people. They go on to say that depending on the degree of integration achieved, based on cultural understandings, beliefs and trust, will determine how effective the organization will be.[23] Burt & Knez note, "trust is committing to an exchange before you know how the other person will reciprocate" (p.69).[24] Borgatti & Foster (2003), on the other hand, characterize network organizations as "repetitive exchanges among semi-autonomous organizations that rely on trust and embedded social relationships to protect transactions" (p.995).[25] To explain network organizations Ishida (2002) employs four environmental parameters: nature of the task, amount of decision making, size of organization and communication cost. Other scholars list different characteristics like: fidelity, agility, social interaction based on trust, shared values and beliefs as described by Atkinson & Moffat (2005) which lead to the sharing of information.[26]

Network organizations are typically flattened work structures, self-governed and rely on lateral peer-to-peer communications.[27] The lateral communication is a key factor,

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[21] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 17.

[22] Grant T. Hammond, *The Essential Boyd*. 6 Oct. 2006. http://www.belisarius.com/modern_business_strategy/hammond/ essential_boyd.htm April 2008.

[23] Atkinson and Moffat, 2005, *The Agile Organization* 2005), 13.

[24] Monge and Contractor, Theories of Communication Networks, 213.

[25] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 37.

[26] Atkinson and Moffat, 2005, *The Agile Organization* 2005), 89-90.

[27] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 38.

according to Monge & Contractor (2003), because most of the crucial information that people receive is from others with whom they communicated on a regular basis. One of the advantages here is; anytime a new person joins the network they bring with them knowledge, experience, skills and expertise that is not necessarily known to the organization. This in turn has the potential to bring new energies to the organization.[28] However, in order to be considered as an organization there needs to be some reference to knowledge and information. Atksinson & Moffat (2005) contend there are three levels of knowledge and information within the network. The three levels of knowledge are: 1) tacit – which is inexpressible, 2) implicit – which is embedded knowledge within mental models and 3) beliefs – which can be accessed and expressed. Information is what is then shared around the network and as each person receives the information they assign their own meaning to it showing the diversity and depth the network organization has.[29]

Leweling (2007) postulates that network organizations provide a clear parallel to organic organizational structures and Edge organizations which when considered by their separate parts, mechanisms, parameters and factors can be analyzed as hybrids.[30] And finally, Atkinson & Moffat (2005) argue that the reason network organizations exist or develop is to produce "action" where formal processes fail.[31] Van Alstyne (1997) summarize these ideas, saying: " the network form is designed to handle tasks and environments that demand flexibility and adaptability" and "it has become increasingly clear that the organizational form associated with flexible specialization is the network, although we have not always used that term."[32]

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[28] Monge and Contractor, Theories of Communication Networks, 96-147.

[29] Atkinson and Moffat, 2005, *The Agile Organization* 2005), 89-90.

[30] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 38.

[31] Atkinson and Moffat, 2005, *The Agile Organization* 2005), 89-90.

[32] Van Alstyne, M. 1997. The state of network organization: a survey in three frameworks. *Journal of Organizational Computing & Electronic Commerce*, 7(2/3): 131.

B. PREVIOUS WORK ON NOISE FILTERING WITHIN TEAMS/ORGANIZATIONS

This section will explore some of those characteristics researchers believe influence organizational performance as well as information and knowledge. This section will also discuss noise filtering in relation to information and knowledge. Specifically, how noise is not necessarily information nor is it knowledge but instead noise resides somewhere between the two.

First, there are many attributes mentioned throughout previous papers that researchers contend contribute to higher performing organizations. Topping the list is size: many researchers (Baumler 1971, Mintzberg 1983, Guzzo & Dickson 1996, Robbins 2000) posit that smaller organizations outperform larger organizations in environments with more uncertainty. Other high-performing characteristics according to Robbins (2000) include: team members having different types of skills (technical, problem solving/decision making or interpersonal skills), team members properly matched to their roles, commitment to a common purpose, specific goals, strong leadership and structure to provide focus and direction and high mutual trust amongst members.[33] Dodd (2006) suggests the following organizational attributes: identity and sense of self, generation, maintenance and dissemination of purpose, groupings of operating units, decision making ability, shared awareness, perception of environment and changes, status monitoring, synergy and success measures.[34] Finally, Pearce & David (1983) suggest the following group structural properties positively impact performance: high centrality, few coalitions, few isolates, many stars, many liaisons, high connectedness and high reciprocity. Pearce & David (1983) continue also claim these properties negatively impact performance: many coalitions, many isolates, few stars, few liaisons, low connectedness and low reciprocity.[35] Although the list of "high

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[33] Robbins, Stephen P. *Essentials of Organizational Behavior.* Upper Saddle River, N.J.: Prentice Hall, 2000.

[34] Lorraine Dodd, "Experiments into the operation and effectiveness of Edge Organization" Command and Control Research &Technology Symposium (San Diego, CA, June, 2006), 6.

[35] John A. Pearce II and Fred R. David, "A Social Network Approach to Organizational Design-Performance," Academy of Management Review (July, 1983), 441.

performing" characteristics/attributes mentioned above is not all inclusive there is no mention in any reference regarding noise filtering. One goal of this thesis is to establish noise filtering as a characteristic that contributes to the high performance of organizations.

The term information has acquired new meanings in recent years. Arquilla & Ronfeldt (1996) discuss information as falling into one of three general views: information as message, information as medium and information as physical matter. For purposes of this thesis only information as message will be further explored. Information as message is an immaterial message or signal that contains meaningful content and can be transmitted. This type of information is most often found in the form of "reports, instructions and programs."[36] They go on to describe an "information pyramid" that starts with a broad base called data. The next layer up is information, knowledge and at the top is wisdom. Information has also been described in terms of information categories. Bystrom & Jarvelin (1995) describe three information categories: problem information, domain information and problem-solving information. Problem information consists of properties and requirements of the problem. Domain information consists of known facts, concepts and theories within the problem environment. Problem-solving information covers the methods of how problems should be seen and formulated.[37] From the two explanations above we might infer that noise closely reassembles the view of information as message or the category of domain information however based on the information pyramid there is a fine line between information and knowledge. This can also be summed up by Leweling (2007), "what constitutes information in one context may be construed as knowledge in another."[38]

There have been many debates over the nature of knowledge. One element researchers (Barsalou, 1992; Argote, 1999) tend to agree on is that knowledge is a

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[36] John Arquilla and David Ronfeldt. *Information, Power, and Grand Strategy: In Athena's Camp* (The Information Revolution and National Strategy: Dimensions and Directions, 1996), 145.

[37] Byström, K., & Järvelin, K. 1995. Task complexity affects information seeking and use. *Information Processing & Management*, 31(2): 195-196.

[38] Tara Leweling. *Extending Organizational Contingency Theory To Team Performance – An Information Processing and Knowledge Flows Perspective*, Naval Postgraduate School, 2007, 47.

difficult entity to measure. Becerra (2001) identifies a number of different categories of knowledge: tacit, embodied, encoded, embrained, embedded, event and procedural; while Birkinshaw et al (2002) discusses a number of different types of knowledge: tacit, hard to observe, complex, system dependent, articulate, observable in use, simple and system independent. Both agree that it is useful to distinguish between "information" and "know-how" as two types of knowledge, viewing them as "what something means" and "knowing how to do something." In this context information is knowledge which can be transmitted without loss of integrity and know-how is the accumulated experience that allows one to do something smoothly and efficiently.[39] Noise filtering does not necessarily fit into information or knowledge but instead fits somewhere in between.

This thesis is an attempt to analyze characteristics at the micro level to determine which characteristics contribute to high performance in organizations, starting with an investigation of noise filtering.

C. EDGE V. HIERARCHY

The interactions among members are restricted in the Hierarchy structure to one's direct supervisor or subordinates. The span of control for the Hierarchy structure was set in the Industrial Age and ideally sits at five to seven levels.[40] Command and control is achieved by centralized planning, decomposition of tasks and deconfliction of control processes. Hierarchies are notorious for producing stovepipes that take on their own culture and language which also causes information flows to evolve into stovepipes.[41]

Edge configurations, on the other hand, encourage interactions between all members. Command and control is achieved first by uncoupling the two. As a result, control is not a function of command but rather a function of the environment and the adversaries. Command sets the initial condition and provides overall intent. Edge organizations are very agile and allow information to be combined in new ways making it

39 Birkinshaw, Nobel, & Ridderstrale, 2002. Knowledge as a contingency variable: Do the characteristics of knowledge predict organization structure? Organization Science, 13(3): 276.

40 Alberts and Hayes, *Power to the Edge*, 42.

41 Alberts and Hayes, *Power to the Edge*, 215-216.

possible to meet the needs of a variety of situations. Although not optimized to accomplish familiar tasks, like Hierarchy structures, they are well suited to deal with higher degrees of uncertainty and unfamiliarity due to Edge organizations facilitating the sharing of knowledge, experience and expertise.[42]

Edge consistently outperforms the Hierarchy organizational form in complex environments that are filled with high levels of uncertainty and unfamiliarity, as proven by many researchers: Orr & Nissen (2006) and Leweling (2007). Some comparative characteristics between Edge and Hierarchy are captured in Figure 1. Now the question is: what characteristic at the micro-level contributes to the outperformance?

	Hierarchies	Edge Organizations
Command	By directive	Establishing conditions
Leadership	By position	By competence
Control	By direction	An emergent property
Decisionmaking	Line function	Everyone's job
Information	Hoarded	Shared
Predominant Information Flows	Vertical, coupled with chain of command	Horizontal, independent of chain of command
Information Management	Push	Post - Pull
Sources of Information	Stovepipe monopolies	Eclectic, adaptable marketplaces
Organizational Processes	Prescribed Sequential	Dynamic Concurrent
Individuals at the Edge	Constrained	Empowered

Figure 1. Comparison of Attributes of Hierarchies and Edge Organizations from Alberts & Hayes (2003)[43]

[42] Alberts and Hayes, *Power to the Edge*, 216-217.

[43] Alberts and Hayes, *Power to the Edge*, 218.

D. STATEMENT OF HYPOTHESIS

Tushman & Nadler (1978) posit that organizations are formed to reduce work-related uncertainty, and that "a critical task of the organization is to facilitate the collection, gathering and processing of information" (p. 614). In particular, they specify that organizations in which the information processing structure matches the information processing environment will outperform organizations in which structure and environment are mismatched. Further, highly effective organizations will adapt their information processing structures as the environment changes.

From these postulates, we analyze the information processing behaviors of four groups of mid-level working professionals as each undertakes a series of four complex, interdependent, computer-mediated decision-making exercises to explore 1) how processing of information in effective (i.e., high-performing) groups differs from the processing of information in ineffective (i.e., low-performing) groups, and 2) the characteristics of adaptation, from an information processing perspective, within high performing groups. Pearce & David (1983) assert performance of emergent structures can be tested by means of social network measures.[44] Leweling (2007) argues that with the successful creation of knowledge amongst individuals and providing a means of sharing that knowledge; organizations generate a competitive advantage.[45]

The following hypotheses test the performance of different organizational structures in complex information processing environment, seeking to uncover the attributes of performance and characteristics of organizations related to structures and individuals.

1. Structure-Level Predictions

The information processing structures that support knowledge sharing filter noise better than those structures that do not support knowledge sharing and the Edge organizational structure filters noise better than the Hierarchy organizational structure.

[44] Pearce and David, Academy of Management Review, 437.

[45] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 190.

Every session of the ELICIT experiment has the same amount of noise distributed at the same intervals. Each actor receives a set of noise at these intervals and then must decide on an action to take. The possible actions an actor may take are either: share or don't share (filter) the "noise". The decision to share or withhold information is also considered one of the most basic observables of sensemaking which enables the "action" behavior.[46] The amount of noised shared has the potential to affect performance by either distracting individuals/groups long enough to cause a delay in their decision or saturating the information space to the point inaccurate or poor decision are made.

H1.1: Structural Influence

Edge organizations filter noise more effectively than hierarchy organizations.

Results from studies such as Carley (1992) indicate that work groups with Edge characteristics may learn at a faster rate than groups with Hierarchal characteristics.[47] Brooks (1994) supports that study by suggesting the Hierarchal structure constrains team knowledge sharing which results in suboptimal performance.[48] However, Beersma et al. (2003) and Balkundi & Harrison (2006) imply that exploring the relationship between structure and performance would be highly productive.[49]

H1.2: Organizations Supporting Knowledge Sharing

Organizations that use knowledge sharing techniques filter noise more effectively than those that do not use knowledge sharing techniques.

In ELICIT the knowledge sharing technique is the postcards which provides a richer communication exchange as well as a mechanism for the players to exchange knowledge.[50] Argote (1999) argues that knowledge management and learning processes

[46] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 44.

[47] Kathleen M. Carley, ORA: the Organizational Risk Analyzer (Pittsburgh, Pennsylvania: Carnegie Mellon University, School of Computer Science, Institute for Software Research International, Center for Computational Analysis of Social and Organizational Systems, 2007).

[48] A.K. Brooks, Power and the production of knowledge: Collective team learning in work organizations. *Human Resource Development Quarterly*, 1994. 5(3): 213-235.

[49] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 52.

[50] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 61.

are entwined resulting in a team's capacity to share, generate, evaluate and combine know.[51] Variance in team performance may be able to be explained by understanding the interaction of information processing structures with knowledge sharing.[52]

H1.3: Structure with Knowledge Sharing Support

Edge organizations that use knowledge sharing techniques filter noise more effectively than others.

Highly centralized, highly formalized structures have restrictive information flows which causes knowledge to become lodged and even attenuate somewhere within the collective leading to suboptimal performance. Likewise, in low centralized, low formalized structures information flows tend to be random and needed knowledge is unlikely to reach the agents who would benefit most from it which also leads to suboptimal performance. However, when the right balance is present then the interaction of structure and knowledge sharing leads to high performance.[53] Leweling (2007) extends existing research to show that team information processing structures coupled with knowledge sharing influence performance.[54] Empirical work done by Becerra-Fernandez & Sabherwal 2001 and Birkinshaw et al. (2002) have closed the gap in literature with their findings on interaction effects between information processing structures and knowledge sharing through explicit.[55]

2. Individual-Level Predictions

The individual people as well as the individual groups (A, B, C and D) that filter noise "better" over time will outperform others that do not.

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[51] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 48.

[52] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 9.

[53] S.L. Brown & K.M Eisenhardt, The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations. *Administrative Science Quarterly*, 1997. 42(1): 1-34.

[54] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 187.

[55] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 7.

Whereas the First Substantive Hypothesis deals with information processing structures that support/don't support knowledge sharing as well as specific organization structures, this hypothesis examines individual and group performance over time in terms of filter noise.

H2.1: Individual Performance vs. Time

The ability to filter noise goes up over time within a session.

Specifically, analyzing the total amount of noise shared over time by each individual within a given session. Ideally the noise shared in a session would decrease as time progresses in the session. Leweling (2007) argues that individuals participating in any structure that supports knowledge sharing outperforms similar individuals participating in teams not supported by knowledge sharing. She also offers a rank order of mean individual performance that factors in the above criteria with another based on time; meaning, individuals participating in an Edge structure with knowledge sharing was quicker than Hierarchy structure without knowledge sharing. When the two measures were combined the results were individuals in the Edge structure with knowledge sharing capability outperformed all others.[56] Beersma et al. (2003) predicts a trade-off between time taken to complete a task and accuracy.[57] Applying that logic to this hypothesis, one would expect the longer it takes to submit an identification of the terrorists attack the more accurate it should be and the less noise should be actively being shared. Likewise, the less time taken should result in a less accurate response and a larger quantity of noise actively being shared. In short, it is speculated that the majority of noise shared in a given session would be in the first half of game play.

H2.2: Group Performance vs. Time

The ability to filter noise goes up over time within a group.

Specifically, analyzing the combined amount of noise shared over time for all four sessions within a given group. Ideally with each new session a group completed, the

[56] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 193.

[57] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 98.

noise shared would decrease leading to each session having less noise than the session before it. According to Leweling (2007), work structures that emphasize peer-to-peer relationships can be modeled within a framework of structure, knowledge sharing and performance. This given over time allows groups to develop routineness which should lead to increased performance.[58] Simply put, the longer a group is together and the more times that same group works together the better their performance.

[58] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 4.

III. METHODOLOGY

In this section I build directly upon the work accomplished by Leweling (2007) to provide the reader with a brief background about the experimental environment (ELICIT) used to collect the data for this thesis. Additionally, the information that follows will clearly articulate the techniques used to transform the raw data generated during the ELICIT experiment into the form required for statistical analysis. I will also discuss some key definitions as well as the method used to analyze the data collected from the experiment.

A. INTRODUCTION TO EXPERIMENTAL ENVIRONMENT (ELICIT)

ELICIT is a computer based mediated experiment used to test and compare the performance of two organizational forms; the Edge and Hierarchy. Preliminary results are available in Leweling & Nissen 2007.[59] Specifically, ELICIT allows researchers to manipulate the information processing structures that people are assigned to as well as allowing for the manipulation of knowledge sharing. The information that follows is intended to provide a brief synopsis of ELICIT, its environment and the organizational structures tested within, as they pertain to this paper.

1. ELICIT Environment

There were four distinct groups that participated in the ELICIT experiment. Each group "played" the game 4 different times and for a couple of the groups the configuration changed slightly. The individuals (players) involved in the experiment were asked to identify details of a fictitious terrorist plot. Specifically, they were asked to identify the: who, what, where and when of the scenario. Provided throughout the game were 68 informational clues, also called "factoids". These factoids were distributed

[59] Tara A. Leweling and Mark E. Nissen offer the preliminary results and conclusions of this investigation in a paper entitled "Hypothesis Testing of Edge Organizations: Laboratory Experimentation using the ELICIT Multiplayer Intelligence Game" presented at the 12th International Command and Control Research and Technology Symposium: Adapting C2 to the 21st Century held in Newport, Rhode Island in June 2007.

throughout the group of 17 players at scheduled intervals. Each player received four factoids, two initially, another at five minutes and the forth factoid at ten minutes of game play.[60] The factoids fall within one of four categories that relate to the relevance to the scenario. The categories are: E, K, N and S. An "E" factoid represents expert information and is crucial to solving the scenario. A "K" factoid represents key information and is important to solving the scenario. An "S" factoid is considered supportive; meaning these factoids support the information in the E and K factoid sets. An "N" factoid is not important; meaning the game can be correctly solved if these are ignored.[61] The set of factoids that each player receives will contain an even distribution from the categories which means each play should receive information relevant to the scenario but each set is arranged so that no player receives enough information to correctly identify the entire solution. This makes collaboration necessary among the players in order to solve the scenario correctly. Presently, there are four different versions of the ELICIT game created which are similar in structure but each has its own unique set of factoids. The program also offers the capability of creating more versions, which would allow researchers to script specific scenarios as they see fit however the process is tedious and time consuming. For the purposes of this thesis the "N" factoids are considered noise and as such will be the focus when it comes to noise filtering.

The game is played via separate networked computer workstations that are loaded with the client application. Each client workstation allows the subjects access to the five functions needed to play the game: List, Post, Pull, Share and Identify. The List screen shows all the factoids the player has received, starting with the initial distribution and including any "shared" from other players. Post provides the players the ability to display factoids on a common screen allowing them to be viewed by multiply players. This is done by the player taking a factoid from their List screen and placing it on one of the four (who, what, where or when) Post screens. Pull is the complement to Post and allows factoids to be taken from one of the common (shared) Post screens and placed on

60 Leweling and Nissen, 12th ICCRTS, 5.

61 Parity Communications Inc. 2006. Experiments in command and control within edge organizations: Final report. Washington DC: Command and Control Research Program.

a players own List screen. The solution to the terrorist plot contains four parts: who, what, where and when; so, ideally (provided the factoids have been post to the correct bin, the four Post screens should contain information pertinent to each part of that solution. Share gives the players the ability to send factoids from their list to other players using their pseudonyms (previously assigned). The game limits the players' ability to share information via the two functions of Post and Share; no verbal communication is allowed during the game play. And finally, the last function available to the players is Identify. This function is used by the players to communicate the solution to the terrorist plot of: who, what, where and when.[62] Table 1 below summarizes these functions.

Information processing function	**Short description**
List	Displays received factoids
Post	Places factoid on 'website' for access by other players
Pull	Displays website
Share	Sends factoid to another player – one factoid at a time
Identify	Communications solution

Table 1. Information Processing Functions from Leweling 2007[63]

Throughout the game, the server application captures transaction data in the form of text-file logs. These logs are time stamped to the nearest second and nearly every activity that occurs during the game is registered in these log files to include: which, when and to whom factoids were distributed, posted, pulled and shared. The log files also records when and what each player identifies as the solution. Researchers are then able to process the log files in whatever way is convenient for them in order to distill the information they want.[64] For this thesis the author coded the data in the log files into time demarcated matrices which were then evaluated with a statistical analysis software.

[62] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 55-57.

[63] Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 57.

[64] 64 Leweling and Nissen, 12th ICCRTS, 5.

2. Modeling Edge and Hierarchy Structures in ELICIT

One of the primary variables to be examined by ELICIT is the performance differences between the Edge and Hierarchy forms. The experiment has modeled each form in order to test and compare them at the micro-level. The organizational forms are very different however they do have similarities. First, regardless of the configuration, a subject is assigned to one of four groups which correspond with a part of the Identify function; there is a “who” group, “what” group, “where” group and “when” group. After a subject is assigned to a group; they remain part of that group throughout each session of the experiment. Another important similarity is the ability to share information. In both configurations the subjects have unfettered access to share with any of the other 16 players simulating the “flattening” effect of e-mail or other widespread communications that enable collaboration amongst peers across formal organizational boundaries. Although there are similarities, the differences are what make the comparison worthwhile. The figure below illustrates how dynamic the Edge organization can be.

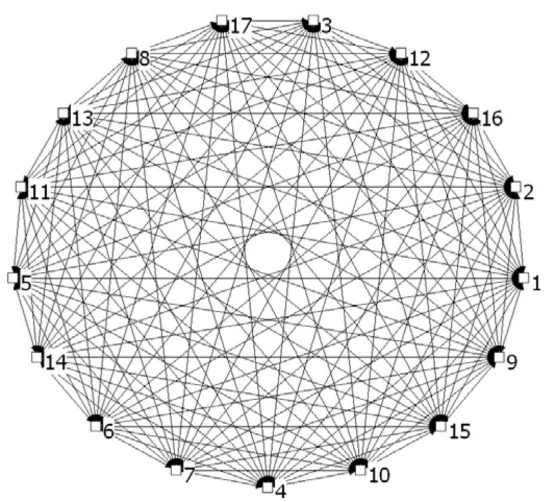

Figure 2. Edge Organization from Leweling 2007[65]

While playing in the Edge configuration, there are no “leaders”, everyone is of equal status plus the players are allowed to post to or pull from any of the common screens. Specifically, a player that belongs to the “who” group has the ability to Post to and Pull factoids from the “who” screen as well as Post to and Pull from the “what” screen, the

65 Leweling, 2007. *An Information Processing and Knowledge Flows Perspective*, 70.

"where" screen and/or the "when" screen. Also within the Edge configuration the players have the capability to send postcards to any other member of their choosing. The postcards in ELICIT are suppose to represent the knowledge sharing portion of the experiment. The Hierarchy configuration however is significantly different. For starters, players are assigned roles or positions within a three-level hierarchical structure as shown in Figure 2.

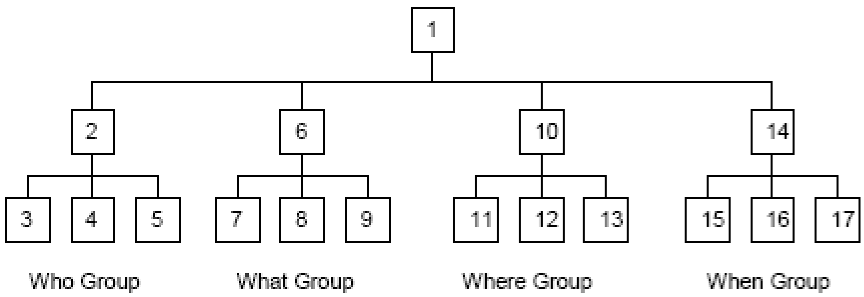

Figure 3. Hierarchy Organization from Leweling & Nissen 2007b

As shown in Figure 3, there is an overall leader (i.e., labeled "1") who is responsible for the intelligence organization as a whole. Reporting directly to the overall leader are four functional leaders (i.e., labeled "2," "6," "10," and "14") each of whom are in charge of three analysts assigned to their groups and is responsible for one set of the details associated with the terrorist plot (who, what, where and when). The interactions between these groups are very limited in the Hierarchy form. Every player has truncated access to the common screen except for the overall leader. For instance, a member of the "who" group is only able to Post to and Pull from the "who" common screen but the overall leader has access to all four common screens and as such can Post to and Pull from any of the four as they see fit. The players are still however able to pass factoids to any other player via the Share function.[66] The postcards in the Hierarchy form are also restricted. In this configuration; a player at the lowest level is only permitted to share postcards with members of their own group, while functional leaders are allowed to share with members of their specific group or the overall leader and the overall leader may share postcards with anyone. While factoids represent information sharing, postcards represent a

66 Leweling and Nissen, 12th ICCRTS, 8.

snapshot of how a player understands the information at a certain moment in time. Therefore you could say sharing postcards is the equivalent of sharing knowledge.[67] More information about the use of Postcards and the results of the hypotheses associated with them can be found in Leweling & Nissen, 2007b.

B. CONVERTING LOG FILES

For this thesis all sixteen log files generated during the ELICIT experiment are analyzed. As mentioned above, each log file captures the time and type of interaction that occurs between players. These events are displayed in a text document where on each line is recorded the details of the event: who, what, where and when. Each experimental session lastly roughly one hour and by the end of a session the log file generated is approximately one hundred and fifty to two hundred pages in length (using the formatting of this thesis). Before extracting the data from the log files into matrices, they are converted from text files into Excel workbooks which allow for sorting of agent names, event types, times and factoid numbers. This enables a much more efficient transfer of data.

In order to analyze the data in the log files the author first had to create matrices for each file. A matrix possesses all the subjects' names as column headers and a function of noise as the row headers. The example in Table 2 shows the activity of noise (row) as it relates to each subject (column):

[67] Leweling and Nissen, 12th ICCRTS, 10-12.

	Alex	Chris	Dale	Francis	Harlan	Jesse	Kim	Leslie	Morgan	Pat	Quinn	Robin	Sam	Sidney	Taylor	Val	Whitley
Tot. Share	40	0	0	0	0	0	0	2	0	3	0	4	0	34	0	0	32
Noise	1	0	0	0	0	0	0	0	0	0	0	2	0	17	0	0	16
Noise %	0.03	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.00	#DIV/0!	0.00	#DIV/0!	0.50	#DIV/0!	0.50	#DIV/0!	#DIV/0!	0.50
# Different Noise Facts	1	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1

	Alex	Chris	Dale	Francis	Harlan	Jesse	Kim	Leslie	Morgan	Pat	Quinn	Robin	Sam	Sidney	Taylor	Val	Whitley
Tot. Post	4	13	5	5	0	4	10	4	7	16	0	1	9	7	1	3	6
Noise	1	7	2	3	0	1	4	2	3	7	0	1	4	4	0	0	3
Noise %	0.25	0.54	0.40	0.60	#DIV/0!	0.25	0.40	0.50	0.43	0.44	#DIV/0!	1.00	0.44	0.57	0.00	0.00	0.50
# Different Noise Facts	1	4	2	3	0	1	2	2	2	3	0	1	2	3	0	0	1
N. Posted	1	7	2	3	0	1	4	2	3	7	0	1	4	4	0	0	3
Prop Bins	0	4	1	0	0	1	2	1	2	3	0	0	1	2	0	0	2
% Proper	0.00	0.00	0.50	0.00	#DIV/0!	1.00	0.50	0.50	0.67	0.43	#DIV/0!	0.00	0.25	0.50	#DIV/0!	#DIV/0!	0.67
O. Posted	3	6	3	2	0	3	6	2	4	9	0	0	5	3	1	3	2
Prop Bins	2	4	2	1	0	1	2	1	2	4	0	0	2	2	0	1	2
% Proper	0.00	0.67	0.67	0.50	#DIV/0!	0.33	0.33	0.50	0.50	0.44	#DIV/0!	#DIV/0!	0.40	0.67	0.00	0.33	1.00

Table 2. Example of Noise to Subject Matrix

The matrices are saved in Excel workbooks. Each experiment date is compiled in a separate Excel file. Each file is further broken down into separate workbooks to simplify the conversion of the data. I used a minimum of four workbooks for any given experiment date. The main workbook was the conversion of the log file imported into Excel providing the information as indicated above. A second workbook was used for factoid numbers. This allowed for a more rapid error checking for identifying "noise" factoids compared to all other factoids present during that session. The last two workbooks were the results workbooks to include graphs. First the example listed in Table 2 illustrates every player for each session and the number of factoids shared and posted by each. The factoids shared are further analyzed to reveal how many of the factoids shared were noise, the percentage of noise shared and the number of different noise factoids shared by each person. The matrix also covers noise posted versus non-noise factoids posted and again shows quantity as well as percentages of each. The "posting" data is further expanded to capture whether or not factoids were posted in the proper bins; meaning if it was a "who" factoid was it posted on the "who" website and so on. Finally the last workbook of the results workbooks is illustrated in Table 3 below. This workbook captures the factoids shared and posted over time.

Minutes	5	10	15	20	25	30	35	40	45	50	55	60
Tot. Share	34	3	1	6	28	17	25	1	0	0	0	0
Noise	16	1	0	1	16	1	1	0	0	0	0	0
Noise %	0.47	0.33	0.00	0.17	0.57	0.06	0.04	0.00	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Tot. Post	45	23	16	3	7	0	1	0	0	0	0	0
Noise	17	15	4	3	3	0	0	0	0	0	0	0
Noise %	0.38	0.65	0.25	1.00	0.43	#DIV/0!	0.00	#DIV/0!	#DIV/0!	0.00	#DIV/0!	#DIV/0!
N. Posted	17	15	4	3	3	0	0	0	0	0	0	0
Prop Bins	6	6	3	2	2	0	0	0	0	0	0	0
% Proper	0.35	0.40	0.75	0.67	0.67	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.00	#DIV/0!	0.00
O. Posted	28	8	12	0	4	0	1	0	0	0	0	0
Prop Bins	16	2	5	0	1	0	1	0	0	0	0	0
% Proper	0.57	0.25	0.42	#DIV/0!	0.00	#DIV/0!	1.00	#DIV/0!	#DIV/0!	0.00	#DIV/0!	0.00

Table 3. Example of Total Noise Over Time Intervals

In this example, the number of factoids shared and posted is captured at every five minute interval for each session. The factoids shared are further analyzed to reveal how many of the factoids shared were noise, the percentage of noise shared and the number of different noise factoids shared at each five minute interval. The matrix also covers noise posted versus non-noise factoids posted and again shows quantity as well as percentages of each. The "posting" data is further expanded to capture whether or not factoids were posted in the proper bins; meaning if it was a "who" factoid was it posted on the "who" website and so on. In addition to facilitating more rapid error checking, this method allows the researchers to evaluate how much noise is shared over time, if the number decreases over time and possible "learning" going on. After the Excel workbooks are completed the data were statistically analyzed to hopefully prove hypothesizes mentioned.

Finally, the researcher selects the desired output measures and then calculates the desired measures which are the independent variables. Again, this thesis examines the noise filtering accomplished by individuals and noise shared over time intervals. Chapter IV details the specific formulas used to calculate the independent variables for each hypothesis.

C. DEFINITION OF HIGH PERFORMANCE

Building on Leweling (2007), the measurements can be grouped by performance and learning. Hypotheses 1a, 1b and 1c would be indicative of the information processing and knowledge sharing functions at the high level group setting. Specifically, theses three hypotheses address the different organizational structures (Edge versus Hierarchy) and the mental model differences (shared versus not shared) as a whole. Hypotheses 2a and 2b address the issues mentioned above at a lower level. Specifically, these two hypotheses address performance and learning at the level of each individual session and at the individual group level; meaning Group A, B, C or D.

1. Time (speed)

This is the first component of performance and is defined as the time it takes for a player to submit his or her identification of the terrorist plot. Group performance is then calculated to be the mean submission time of all players participating in a particular experimental session. For ease of comparison, the measurements for both time scales are normalized with a 0-1 scale, with 1 representing the quickest time for submission. Measurements are easy to construct since all identifications are time stamped in the log files produced by ELICIT. In order for the comparison of times to be meaningful from one session to another, the general assumption is made that the clock times of all sessions are equivalent. For example, a submission at 2200 seconds after the start of Session 1 is considered to be exactly as quick as a submission at 2200 seconds after the start of Session 2. Each player's normalized identification time is thus derived from Equation 1, where 3896 represents the maximum time (in seconds) elapsed during all 16 experimental sessions:

$$\text{Equation 1: } T = \frac{3896 - identification\_time}{3896}$$

In other words, in order to calculate the normalized identification time for a submission occurring at 2200 seconds after the start of any of the 16 experimental sessions, one

would substitute 2200 in place of the *identification_time* in the equation above:[68]

$$\frac{3896-2200}{3896}=.44$$

2. Accuracy

The second component of performance is accuracy. Accuracy refers to the specific details of each players' identification relating to the terrorist plot – i.e., who, what, where and when. It is measured by awarding for each component of the correct answer – group, target, country, month, date and time of day; then that score is transformed to a linear scale of 0-1, with equal weight to each of the components (who, what, where and when). Thus a perfect submission, where all four parts are correct would receive a 1, while a blank or completely inaccurate submission would be a 0. Group performance would again be the mean accuracy of each participant's identification.[69]

D. DEFINITION OF NOISE FILTERING

In the ELICIT experiment fifty percent of all factoids in any given scenario are coded as "N" and as such are considered noise; this means that the factoid provided absolutely nothing to the solution of the terrorist plot. Noise filtering is the capacity to recognize which factoids are noise and ignoring those factoids. Specifically, the noise factoids would not be posted to any of the common screens nor would they be shared with any of the other players. Ideally, in a utopia, the only noise factoid transaction we would see in the logs would be the initial distribution of the factoids to the players and nothing else. However, if noise is going to be shared or posted on a common screen, we would hope that it decreases over time, indicating a learning process going on at the team and individual levels.

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[68] Leweling and Nissen, 12th ICCRTS, 10-11.

[69] Leweling and Nissen, 12th ICCRTS, 11.

E. STATISTICAL ANALYSIS

Once the independent and dependent variables have been processed or calculated, the researcher must then determine which statistical tests are appropriate for comparing the variables and determining whether or not there is a correlation between them.

1. Structure-Level Measures

The structure-level hypotheses compare performance between the two organizational forms. The data were tested to determine normality with the Kolmogorov-Smirnov test; however the data are expected to be normally distributed. Provided the data produces a normal distribution (i.e., $p > .05$) it will be appropriate to test the hypotheses with ANOVA and Pearson's tests for correlations.

2. Individual-Level Measures

Each Individual-Level hypotheses compare performance between individual groups over time. The data will be tested to determine normality with the Kolmogorov-Smirnov test; however the data is expected to be normally distributed. Provided the data produces a normal distribution (i.e., $p > .05$) it will be appropriate to test the hypotheses with ANOVA and Pearson's tests for correlations.

F. SUMMARY

This chapter describes the ELICIT environment, extending the work of Leweling & Nissen (2007), to include the Edge and Hierarchy configurations within the experiment and proceeds to outline the techniques used to convert the data recorded during the experiment into reliable measures of noise shared over time intervals as well as by each individual, the independent variables analyzed in this thesis. Performance, in terms of time and accuracy, are the dependent variables of this analysis. Finally, the independent and dependent variables are checked for correlations. The results of these efforts are described in the subsequent chapter.

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IV. RESULTS AND ANALYSIS

This chapter discusses the results and analysis of the hypotheses introduced in Chapter II. Two different entities were analyzed in this thesis: organizational structure and individuals. Section A presents the findings of Structure-Level analysis, while Section B presents Individual-Level analysis. The chapter concludes with Section C which is a discussion of the results.

A. STRUCTURE-LEVEL ANALYSIS

In this section, I described the results for the hypotheses mentioned in Chapter II on the information processing structures that support knowledge sharing versus those structures that do not support knowledge sharing in relation to their noise filtering capability as well as the Edge organizational structure versus the Hierarchy organizational structure and their capability to filter noise.

1. H1.1: Structural Influence

Hypothesis 1.1 predicts that Edge organizations filter noise more effectively than Hierarchy organizations. To test this hypothesis, I compared the percentage of noise shared in the Edge organization to the percentage of noise shared in the Hierarchy organization. The aggregate number of each (Edge = .28, Hierarchy = .39) suggests there is a difference worthy of further investigation. Next, I compared the performance means between Edge organizations (percentage of noise shared in Edge = .28, $\mu = .35$, $\sigma = .13$, $\sigma^2 = .02$) against Hierarchy organizations (percentage of noise shared in Hierarchy = .39, $\mu = .39$, $\sigma = .08$, $\sigma^2 = .01$). Lastly, I use the means listed above to calculate the mean of all noise shared in both groups ($\mu = .37$, $\sigma = .03$, $\sigma^2 = .001$) against the mean of all noise shared between groups ($\mu = .37$, $\sigma = .11$, $\sigma^2 = .01$). The variations in this last analysis suggest there is not enough evidence to accept this hypothesis.

2. H1.2: Organizations Supporting Knowledge Sharing

Hypothesis 1.2 predicts that organizations that use knowledge sharing techniques filter noise more effectively than those that do not use knowledge sharing techniques. To test this hypothesis, I compared the percentage of noise shared in the organizations that used knowledge sharing techniques (MM) to the percentage of noise shared in organizations that did not use knowledge sharing techniques (no MM). The aggregate number of each (MM = .33, No MM = .36) suggests there is a slight difference worthy of further investigation. Next, I compared the performance means between organizations that used knowledge sharing techniques (percentage of noise shared in MM = .33, $\mu = .36$, $\sigma = .11$, $\sigma^2 = .01$) against organizations that did not use knowledge sharing techniques (percentage of noise shared in No MM = .36, $\mu = .38$, $\sigma = .12$, $\sigma^2 = .01$). Lastly, I use the means listed above to calculate the mean of all noise shared in both groups ($\mu = .37$, $\sigma = .14$, $\sigma^2 = .0002$) against the mean of all noise shared between groups ($\mu = .37$, $\sigma = .11$, $\sigma^2 = .01$). The variations in this last step suggest there is not enough evidence to accept this hypothesis.

3. H1.3: Structure with Knowledge Sharing Support

Hypothesis 1.3 predicts that Edge organizations that use knowledge sharing techniques filter noise more effectively than others such as: Edge organizations that do not use knowledge sharing techniques and Hierarchy organizations. To test this hypothesis, I compared the percentage of noise shared in the Edge organizations that used knowledge sharing techniques (Edge w/ MM) to the percentage of noise shared in organizations that did not use knowledge sharing techniques (All Others w/ no MM). The aggregate number of each (Edge w/ MM = .27, All Others w/ No MM = .37) suggests there is a significant difference worthy of further investigation. Next, I compared the performance means between Edge organizations that used knowledge sharing techniques (percentage of noise shared in Edge w/ MM = .27, $\mu = .35$, $\sigma = .14$, $\sigma^2 = .02$) against all other organizations that did not use knowledge sharing techniques (percentage of noise shared in All Others w/ No MM = .37, $\mu = .38$, $\sigma = .10$, $\sigma^2 = .01$). Lastly, I use the means listed above to calculate the mean of all noise shared in both

groups (μ = .36, σ = .02, σ^2 = .001) against the mean of all noise shared between groups (μ = .37, σ = .11, σ^2 = .01). The variations in this last step suggest there is not enough evidence to accept this hypothesis.

B. INDIVIDUAL-LEVEL ANALYSIS

The first three hypotheses mentioned in Chapter II focused on how manipulating information processing structures might influence noise filtering. In this section, I described the results for the hypotheses related to people. The two subsequent hypotheses test the performance on individuals and groups in relation to noise filtering compared against time.

1. H2.1: Individual Performance vs. Time

Hypothesis 2.1 predicts that individuals become more effective at filtering noise over time. To test this hypothesis, I compared the percentage of noise shared by for each session against time based on five minute increments. The mean of the entire experiment as well as the expected curve of effective noise filtering are included in the comparison to provide a better visual baseline. The expected curve for effective noise filtering would start higher at the five minute mark and decrease for each increment afterwards until it levels out close to zero. Figure 4 illustrates the comparison by showing five curves, four of which relate to the first four sessions of the experiment and are appropriately labeled (1, 2, 3, 4) and the fifth line is the mean percentage of noise shared during the entire experiment and is labeled “M”.

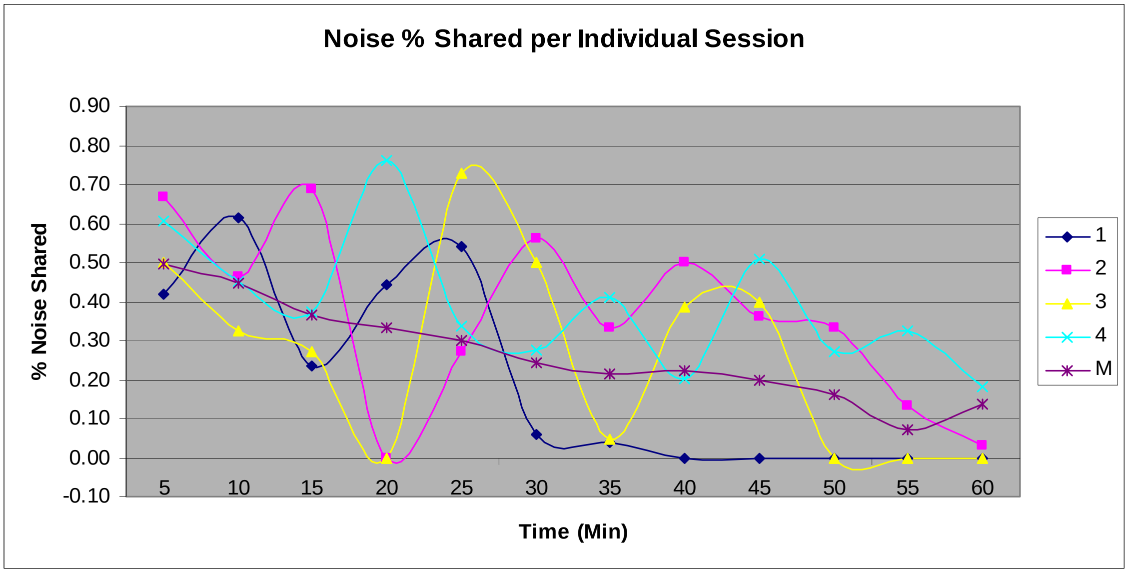

Figure 4. H2.1: Percentage Noise Shared within Sessions 1-4

Figure 5 illustrates the comparison of five curves, four of which relate to sessions 5-8 of the experiment and are appropriately labeled (5, 6, 7, 8) and the fifth line labeled "M" is the mean percentage of noise shared during the entire experiment.

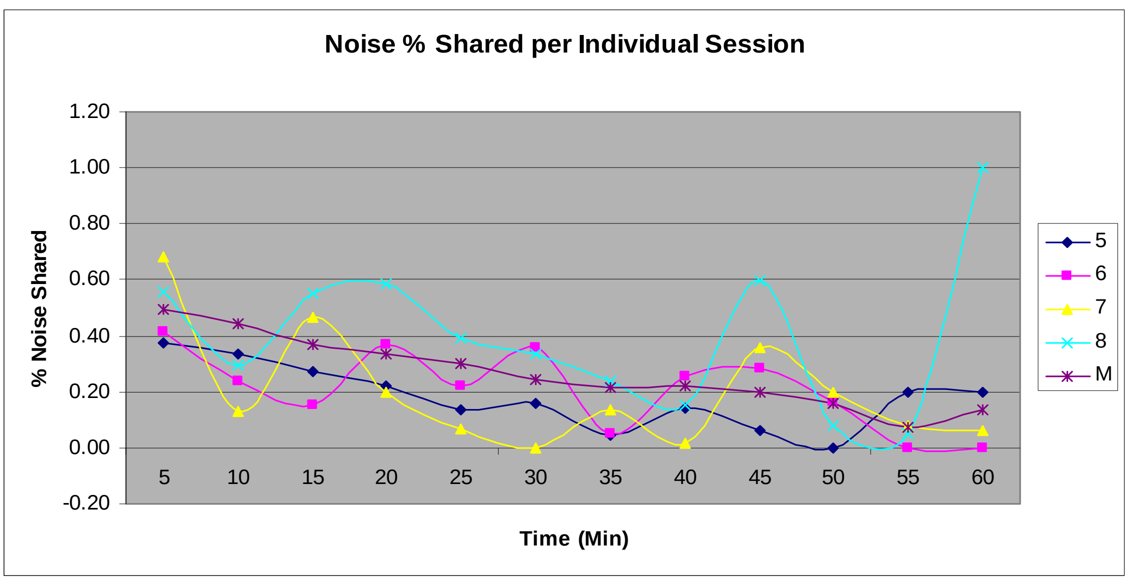

Figure 5. H2.1: Percentage Noise Shared within Sessions 5-8

Figure 6 illustrates the comparison of five curves, four of which relate to sessions 5-8 of the experiment and are appropriately labeled (9, 10, 11, 12) and the fifth line labeled "M" is the mean percentage of noise shared during the entire experiment.

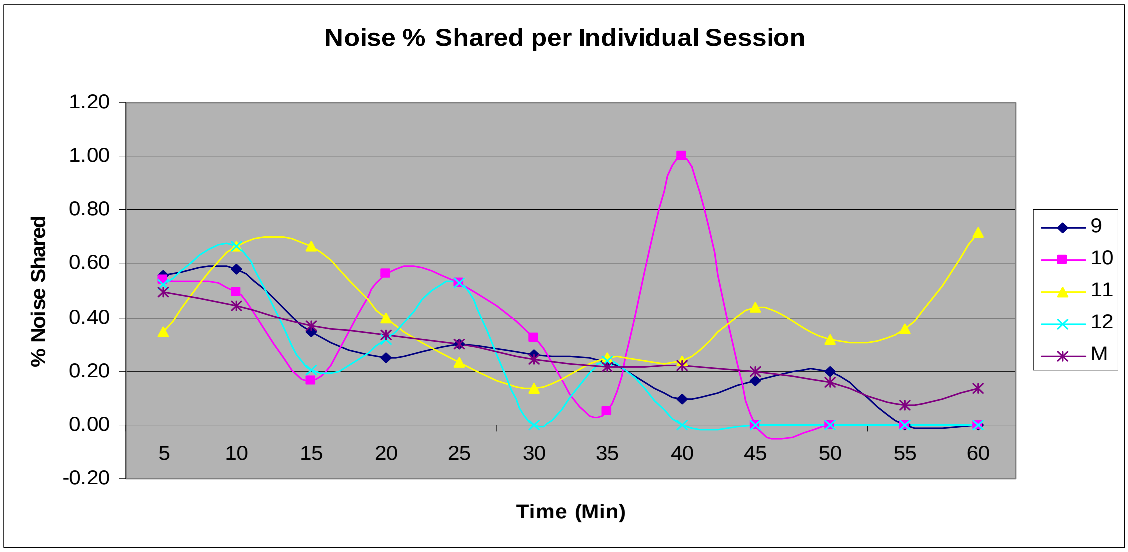

Figure 6. H2.1: Percentage Noise Shared within Sessions 9-12

Figure 7 illustrates the comparison of five curves, four of which relate to sessions 5-8 of the experiment and are appropriately labeled (13, 14, 15, 16) and the fifth line labeled "M" is the mean percentage of noise shared during the entire experiment.

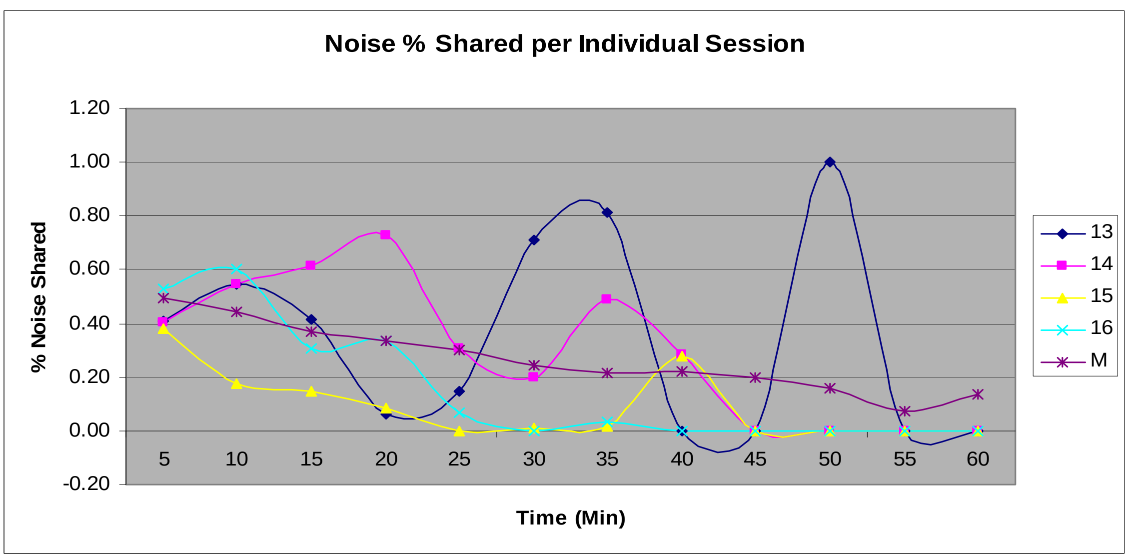

Figure 7. H2.1: Percentage Noise Shared within Sessions 13-16

While the mean closely resembles the expected curve the rest seem to be all over the chart. The unpredictability of the sessions and wide dispersion pattern suggests there is not enough data to accurately access this hypothesis and further testing would be necessary.

2. H2.2: Group Performance vs. Time

Hypothesis 2.2 predicts that groups become more effective at filtering noise over time. To test this hypothesis, I compared the percentage of noise shared by each group for each session against the mean of the entire experiment as well as the expected curve of effective noise filtering. The expected curve for effective noise filtering would start higher in session one and curve down for each session afterwards until it levels out close to zero. Figure 5 illustrates the comparison by showing five curves, four of which relate to the four different groups and are appropriately labeled (A, B, C, D) and the fifth line is the mean percentage of noise shared during the entire experiment and is labeled “M”.

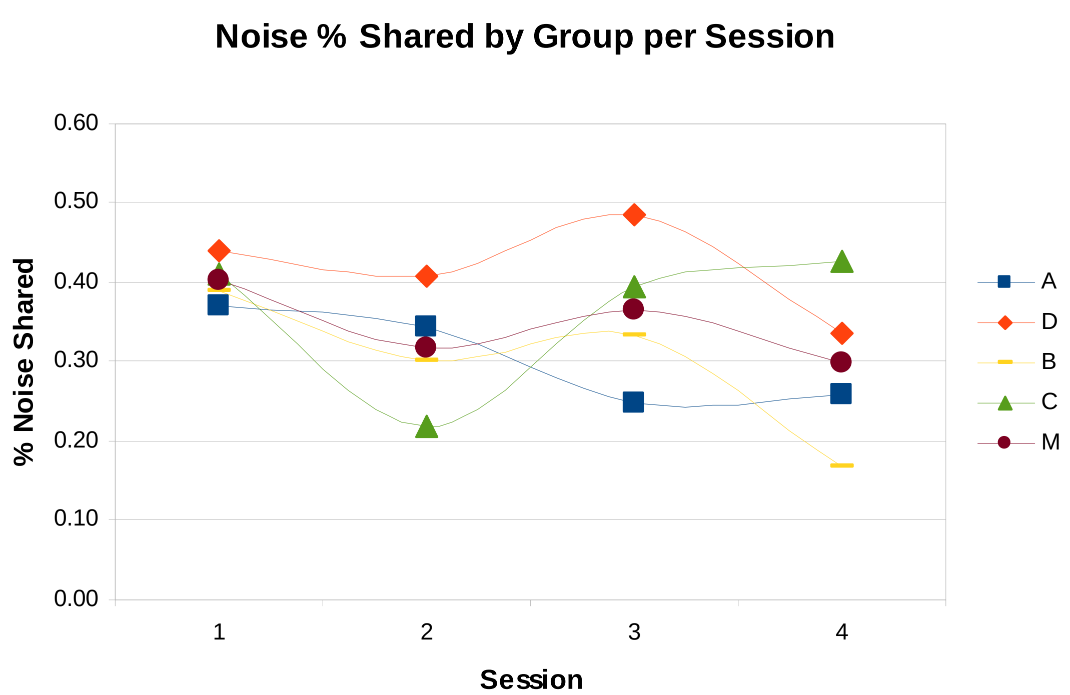

Figure 8. H2.2: Percentage Noise Shared by Group

Although group A came reasonably close to the expected curve of effective noise filtering; the data is insufficient to draw any further conclusions. The wide dispersed pattern suggests there is not enough data to accurately access this hypothesis and further testing would be desirable.

C. DISCUSSION

In this section, I briefly discussed findings of, the three hypotheses concerning the structures of organizations; the two hypotheses relating to individual and group level performance; and unexpected points of interest.

First, the three hypotheses dealing with Structure-Level measures have in common the idea of organizational structure influences the ability to filter noise; organizations that are designed to be flexible and more dynamic should experience an advantage in terms of performance by filtering less noise over organizations that are more rigid and restrictive with their communications. In all cases, there appears to be a statistical difference between and within groups worthy of further research. Unfortunately, none of the organizational structure measures examined in this thesis are useful predictors of noise filtering. Next, the two hypotheses dealing with Individual-Level measures had similar outcomes to the first three hypotheses. There seemed to be a pattern emerging however the final result is there was not enough data to accurately assess these two hypotheses and it would be beneficial to conduct more experiments to exercise the data size for further research.

Based on these assumptions, it seems that the highest performing organizations would be structured in a manner that promotes unrestricted bi-directional communications which fosters learning enabling the ability to filter noise. The ability to filter noise over time demonstrates the cognitive process of learning which can lead to higher organizational performance. Also, as individuals learn to filter noise their performance over time also increases which contributes to the collective group. Although the former may provide better access to information, the flip side is the more noise shared comes at a higher cost in time. Individuals may tend to get inundated with information causing a delay in time which ultimately effects decision making. For these

conjectures to be true two assumptions must be verified. First, the process of individual learning extends to the ability to filter noise. And second, this cognitive learning process translates into more accurate and timelier decision making.

As an explanation, this thesis proposes that as noise filtering increases actors require less time to process and respond to incoming information. This thesis also argues that the more individuals work and interact with the same group that over time they gain knowledge and experience at an increased rate which allows them to distinguish which bits of information are noise and which are potentially useful leading to a more productive and cohesive organization. However, further experimentation is needed to test the validity of these conjectures and bring better understanding to Noise filtering, Information Processing Networks and Organizational Theory.

One surprising result is the range of bandwidth used by the organizational structures. An expected outcome of bandwidth usage would be for the Edge organization to use more bandwidth because it is less restrictive with its communications; however, the opposite appears to be true. Hierarchy appears to use more bandwidth through the sharing and posting functions.

In summary, the results of this thesis are inconclusive but at the same time give further insight into organization structure and information processing theory. More subtle measures and improved techniques are necessary in order to reconcile predictions with observations. It is clear, however, that the dynamic interactions created by the ELICIT experiment in involve more complexity than originally thought; and this added complexity offers future researchers a challenge as well as a wealth of opportunities for studies.

V. IMPLICATIONS FOR THEORIES AND FUTURE RESEARCH

By comparing the information processing behaviors of four groups of mid-level working professionals as each undertakes a series of four complex, interdependent, computer-mediated decision-making exercises, this thesis explored 1) how processing of information in effective [i.e., high-performing] groups differs from the processing of information in ineffective [i.e., low-performing] groups, and 2) the characteristics of adaptation, from an information processing perspective, within high performing groups. The results of the exploration, though mostly inconclusive, call into question both intuition and literature regarding organizational structure as well as literature in information and knowledge sharing. It was predicted that meaningless information (noise) will be shared less as time passes and individuals learn. The result was a slight statistical difference indicating the possibility that noise is shared less overtime. Individual learning was unable to be determined with the small dataset available. It was also hypothesized that as less noise is shared the organizations' performance will increase. The result was the organizations' performance as less noise was shared is inclusive.

Further experimentation is needed to test the validity of these conjectures and bring better understanding to Organizational Theory, Information Processing and Knowledge Sharing networks.

A. REAL WORLD APPLICABILITY

In this section, I discuss how my work could benefit different disciplines and constructs such as military command and control, information processing theory and organizational design.

1. Implications for Military Command and Control

The results of this thesis most readily operationalize to units involved in: defense intelligence fusion, humanitarian relief, small tactical operations and other quick response activities. The ability for these smaller unites to integrate and communications more

effectively by sharing less noise under adverse conditions or in a complex environment could prove to be most useful. More generally, however, the results of this thesis seem to reinforce the idea of presenting people with only the information needed and a method by which to share that information when designing command and control systems. Today's systems should discourage people from seeking out too much information as well as filter noise better to prevent individuals from being overwhelmed with information.

2. Implications for Information Processing Theory

Currently, the ELICIT experimental environment is designed to observe information processing behaviors at the micro-level. The organizations formed within the ELICIT environment can be viewed as information processing units and with the minor adaptations made with noise filtering; it would be useful to understand the difference between information and knowledge processing. In the traditional sender/receiver model of information theory, the noise described is considered physical noise (e.g., other transmissions, power & electronic emissions); however, this thesis posits noise in a different view. Noise, as described in this thesis, is meaningless information that does not contribute to the solution of a problem and is only present to add to the complexity and chaos of a situation. The patterns of communications presented in this thesis are easily observed by the networks created from the merging of the information networks (factoids) and knowledge networks (postcards). As a result, the information processing behaviors, as well as performance can be compared using low levels of irrelevant information (i.e., "noise") versus high levels of irrelevant information. The result verifies noise and ambiguity influence individual and group cognition as the structural level.

3. Implications for Organizational Design

While it can be argued that certain organizational designs work better in certain environments, it is important to remember that organizations are about people and this tends to make organizations very complex systems. The complexity comes from people because they are unpredictable with their thought process which affects their decision

making process. When individuals organize within an environment they tend to share information. Decisions are made based on the information available therefore it becomes extremely important to not add to the complexity of a situation by sharing noise. This can be reduced if the organizations are designed properly. Designing an organization seems to be easier at the macro-level; however this thesis exposes reasons to focus on the micro-level as well. Organizational structures tend to be designed largely in part by their information processing capabilities and needs. An emergent behavior observed in this research however is the ability to filter noise and what role it plays in organizational structures and information processing. This reinforces the notion that flatter, leaner and more flexible organizations are able to make decisions more rapidly. When it comes to designing the micro-level of features of an organization, the results of this thesis indicate that noise filtering should be a consideration as an attempt to maximize performance.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

The ELICIT environment provides researchers with the opportunity to experiment with the configuration by making minor adaptations to operationalize important characteristics. For example, information processing behaviors and resultant performance could be compared relative to conditions of infrequent or no feedback versus high levels or frequent feedback. This leads to potential hypothesizes:

H0: Organizational performance goes up as feedback goes up

H1: Feedback leads to motivating which leads to higher performance

There are other potential research topics that extend from this thesis. First, extending the premise of noise filtering, it would be interesting to analyze how noise is “Posted”. Specifically, when individuals “post” noise to the websites (who, what, where, when) are they posting it in the proper page (e.g., a “who” noise factoid posted to the “who” website). Again, extending on this thesis, researchers could analyze the process of filtering noise a little closer by examining the noise on a time scale; meaning, capture the specific time that a noise factoid is introduced compared to when that same noise factoid is shared. Also, examining to whom and how many times the factoid is shared and the relevance of the factoid. A few questions this generates are: how long until all important

factoids are introduced versus how long those are shared and how are they shared (e.g., websites or "share" function)? Noise filtering could also be analyzed from the "pull" function; how many times people pull noise factoids versus how many times they pull other factoids? The key to the previous is: are people sharing because they have nothing else to do while waiting for more factoids to be distributed by the ELICIT environment because it is considered an awkward silence and this is how people have been programmed to respond. Finally, how much information is filtered (not shared) that is not "noise"?

ELICIT can also be used to examine the effects of a myriad of different forces which act on organization, including: incentive structure, culture and the role of planning and strategy. For incentive structure, we can use the motivation and feedback hypothesizes mentioned above. The culture part can be analyzed by making a few minor alterations to the group dynamics; simply by making the groups a little more diversified. This can be accomplished by running the experiment on groups from different backgrounds (e.g., curriculums, countries, officer, enlisted) and intermingling them so a couple of the experiment groups contain people that have never met. This would correlate with real world deployments where you are working in a joint and coalition environment. Last the role of planning and strategy could be exercised a couple of different ways. First, by introducing deceptive information and analyze how it influences individual and group cognition, information processing and performance. Second, if the ELICIT experiment could be modified to where two opposing groups could play at the same time.

Additional research could test exactly the same hypotheses as the ones developed for this thesis, but with new ELICIT datasets. Ideally a willing researcher would test the hypotheses after more ELICIT experiments have been run to provide a larger data set. The Individual-Level hypotheses mentioned in this thesis would definitely need a larger data set to pull from as well as redefining the hypotheses to better focus them on what is being analyzed. Also, mentioned above was the idea of bandwidth and which structure uses more bandwidth in a complex environment. In summary, the ELICIT environment

is a valuable tool for exploring individuals and groups and provides researchers a means to answer complex questions about organizations and information processing.

C. SUMMARY

Some theorists (Arquilla & Ronfeldt 1996) argue wars and other conflicts in the information age will revolve around organizational factors just as much as technological factors. Tushman and Nadler (1978) posit that organizations are formed to reduce work-related uncertainty, and that "a critical task of the organization is to facilitate the collection, gathering and processing of information" (p. 614). In particular, they specify that organizations in which the information processing structure matches the information processing environment will outperform organizations in which structure and environment are mismatched. Further, highly effective organizations will adapt their information processing structures as the environment changes.

From these postulates, we analyzed the information processing behaviors of four groups of mid-level working professionals as each undertakes a series of four complex, interdependent, computer-mediated decision-making exercises to explore 1) how processing of information in effective [i.e., high-performing] groups differs from the processing of information in ineffective [i.e., low-performing] groups, and 2) the characteristics of adaptation, from an information processing perspective, within high performing groups.

Decisions are often made very quickly. With limited time and limited mental capacity it is not possible to evaluate every goal, problem and alternative which in-turn causes uncertainty. Uncertainty means that decision makers do not have enough information about their surroundings which increases the risk of failure for organizations. The results of this exploration, though mostly inconclusive, call into question the information processing characteristics, the ability to filter noise and their affects on collective performance when operating with uncertainty.

The results from this thesis should be of interest to those who study teams, work groups and organizations at a micro-level. Clearly, however, further experimentation and analysis remains on the proposed hypotheses.

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